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THE FRACTAL NATURE OF WOOD REVEALED BY DRYING

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Nature provides us with a considerable variety of shapes and forms, from the simple to the complex. There is much current interest in the application of fractal geometry¹, to describe the complex phenomena related to the natural shapes and the structure exhibiting an intricate and irregular form. The degree of geometric irregularity of an object can be measured by fractal dimension, such as length of coastlines, molecular surface, aerogels, bacterial colonies, tumor cells, axon terminals, tree crown properties, and so on. Wood is a typical porous material that exhibits interconnected pores composed of biological elements. The pore space consists chiefly of cell cavity, intercellular hole and void in cell wall, which shape a complex structural space of wood. Many reports had shown that the pore space characteristics within wood bear a close relation to the water content, because the structure and size of the pore space changes when water evaporates and escapes from wood. There are also some results on the relationships between the pore space and the water content within wood. Most of them, however, did not take into account the objective regularity and can not reveal the complexity of wood structure.

Introducing the fractal theory into this field will provide new insights. The fractal dimension of wood surface was first studied by using water-sorption. It was found² that the fractal dimension was in the range of 2.5 — 2.8. An experiment³ with pressurized water absorption has confirmed the fractal nature of wood. The findings³ have shown that the pore space within wood could be characterized by fractal dimension or a set of fractal dimensions. But there was no explanation leading to the characterization of wood properties.

A typical property of fractals relates their volume V to the corresponding linear size L , as

$$V(L) \propto L^{df}, \quad (1)$$

where df is in general a non-integral and $df \leq d$. Herein d is the Euclidean dimension of the space in which the object is embedded⁴. This relation is familiar to us when dealing with the usual objects such as lines, discs, or spheres. The mass change (ΔM) of a sample, or the mass of bound water evaporated at different temperatures (T), is a function of the linear dimension (L) of the sample and the drying temperature ($\Delta M \equiv \Delta M(L, T)$). As previously stated, the mass change ΔM represents the volume of the pore space in the cell wall of the sample. Hence from Eq. (1), it can be expressed as

$$\Delta M(L, T) \propto L^{df(P)} \quad (2)$$

where $df(P)$ is the fractal dimension of the pore space in cell walls of a wood sample. The constant of proportionality is not important to us; only the scaling is important to the fractal nature of the structure of pore space. Take the natural

Table 1. The fractal dimensions of Ginkgo and Chinese chestnut obtained at variable temperatures

species	20°C	40°C	60°C	80°C	100°C
Ginkgo	2.106	2.547	2.851	2.863	2.876
Chinese chestnut	2.008	2.566	2.814	2.896	2.972

logarithm of both sides of Eq. (2) and we have

$$\ln(\Delta M) \propto df(P)\ln(L).$$

If a set of ΔM and L is acquired, $df(P)$ can be obtained from a $\log - \log$ plot of the mass change ΔM and the linear dimension L .

The materials for this investigation came from two species, one was a 37-year-old plantation-grown Ginkgo (*Ginkgo biloba*) and the other was a 48-year-old plantation-grown Chinese chestnut (*Castanea mollissima*). After the discs were completely air-dried, they were sawn from pith to bark in the radial direction. Then 11 cubic blocks were sawn near the center of radial face of the discs and sanded. The three dimensions of each cubic block increased in steps of 5mm from 5 mm to 55 mm. The initial moisture of the samples was 14%. The samples were weighed and measured first. Then they were dried in oven at temperatures of 20°C, 40°C, 60°C, 80°C, and 100°C, respectively. The duration of drying was four hours in all cases. After each drying was completed, samples were weighted and measured again.

It was found that the fractal dimensions of the pore space of wood increase as the temperature increases. The fractal dimension is an intrinsic property of the pore space and can be as a new parameter for the characterization of wood. The fractal dimensions obtained in this paper are in the range of 2.1057 — 2.8757 and 2.0080 — 2.9718 for Ginkgo and Chinese chestnut, respectively. They reflect the complexity and irregularity of structure of both woods. The values obtained here for the mass changes $\Delta M(L, T)$ are very sensitive to the nature of the volume of the pore space, and the fractal dimensions should depend on the nature of the escaped water used in the experimental procedure. Compared with the experiment with water at a given pressure, the experiment procedure in this paper is simpler and easier to control. Using this method, the geometric set composed of pores, voids, and micro voids in wood can be described.

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